Operation Of Dry Scrubbers

Introduction

Dry scrubbing, a relatively new control technology, is used on pulverized-coal-fired boilers and municipal waste incinerators. Dry scrubbers use absorption and adsorption to remove sulfur dioxide (SO_2), hydrochloric acid (HCl), hydrogen fluoride (HF), and other acidic gaseous pollutants from a gas stream. Some dry scrubbers also adsorb vaporous organic compounds and metallic compounds.

You should recall from Lesson 2 that absorption is the dissolving of a gas in a liquid solvent. Adsorption is the removal of gases from a gas stream by allowing the pollutant molecules to become attached to a solid's surface. Dry scrubbers are often used in conjunction with ESPs and fabric filters.

Absorption—pollutants are dissolved in a liquid solvent. Adsorption—pollutants are removed from a gas stream when the pollutant molecules attach to a solid's surface.

How Do Dry Scrubbers Operate?

In a dry scrubber, an acidic gas stream is brought into contact with an alkaline reagent. The reagent is in droplet form and either absorbs or adsorbs the pollutants in the gas stream. The droplets containing the pollutants are then dried and collected—usually in an ESP or fabric filter, but sometimes in the bottom of a scrubbing vessel.

Components And Operating Principles Of Dry Scrubbers

Because dry scrubbing technology is relatively new and is still evolving, and because source control requirements differ, several dry scrubbing techniques are currently used. For this lesson dry scrubbing techniques are grouped into three major categories: spray dryer absorption, dry injection adsorption, and combination spray dryer absorption/dry injection adsorption. Spray dryer absorption and dry injection adsorption can be further broken down by specific types:

The three major categories of dry scrubbing techniques are:
- *Spray dryer absorption*
- *Dry injection adsorption*
- *Combination spray dryer/dry injection adsorption*

Spray dryer absorption
- Rotary atomizer spray dryer systems
- Air-atomizing spray dryer systems

Dry injection adsorption
- Dry injection without recycling
- Dry injection with recycling

Figures 5-1, 5-2, and 5-3 are simplified block diagrams of the three major types of dry scrubbing systems.

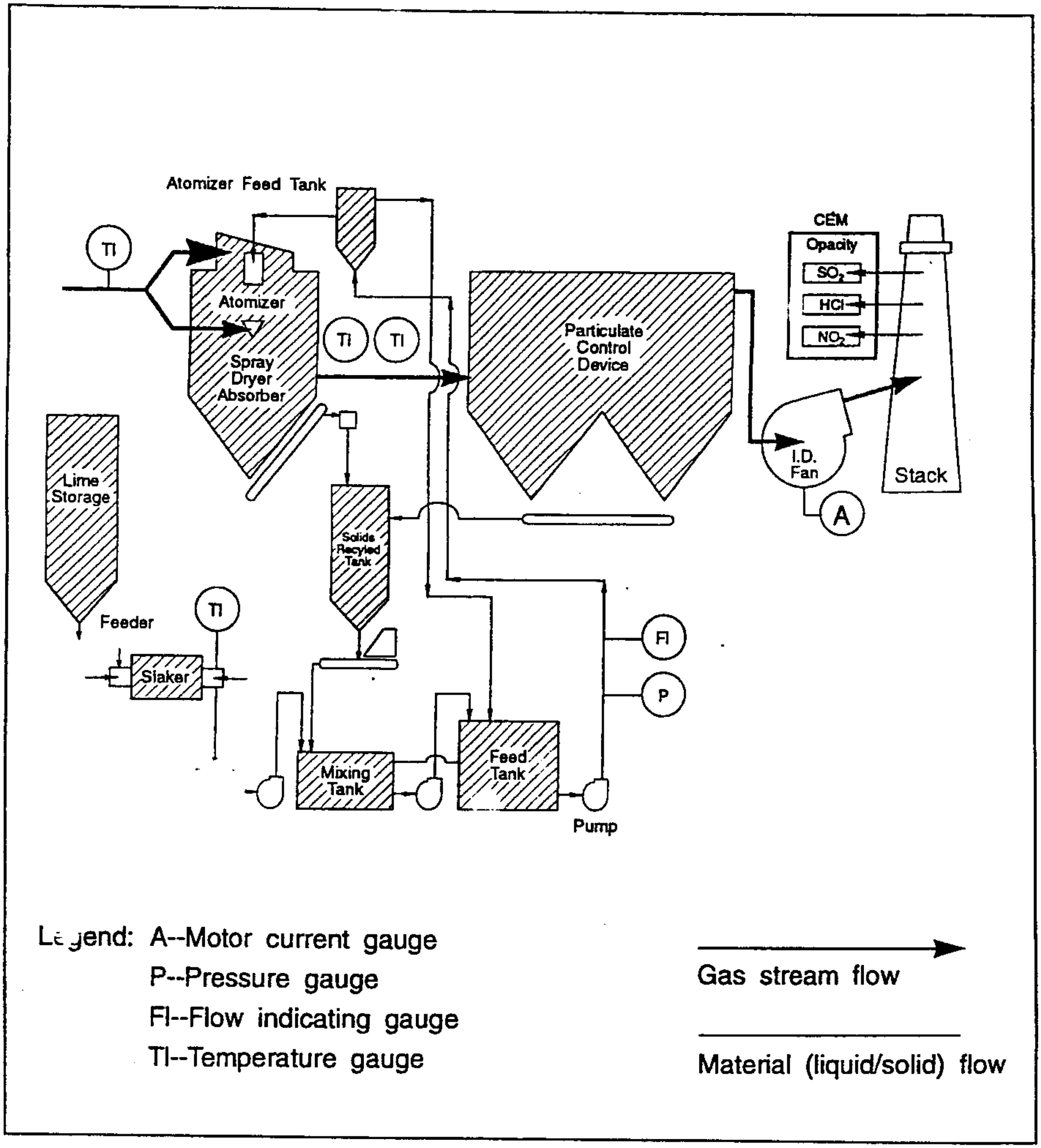
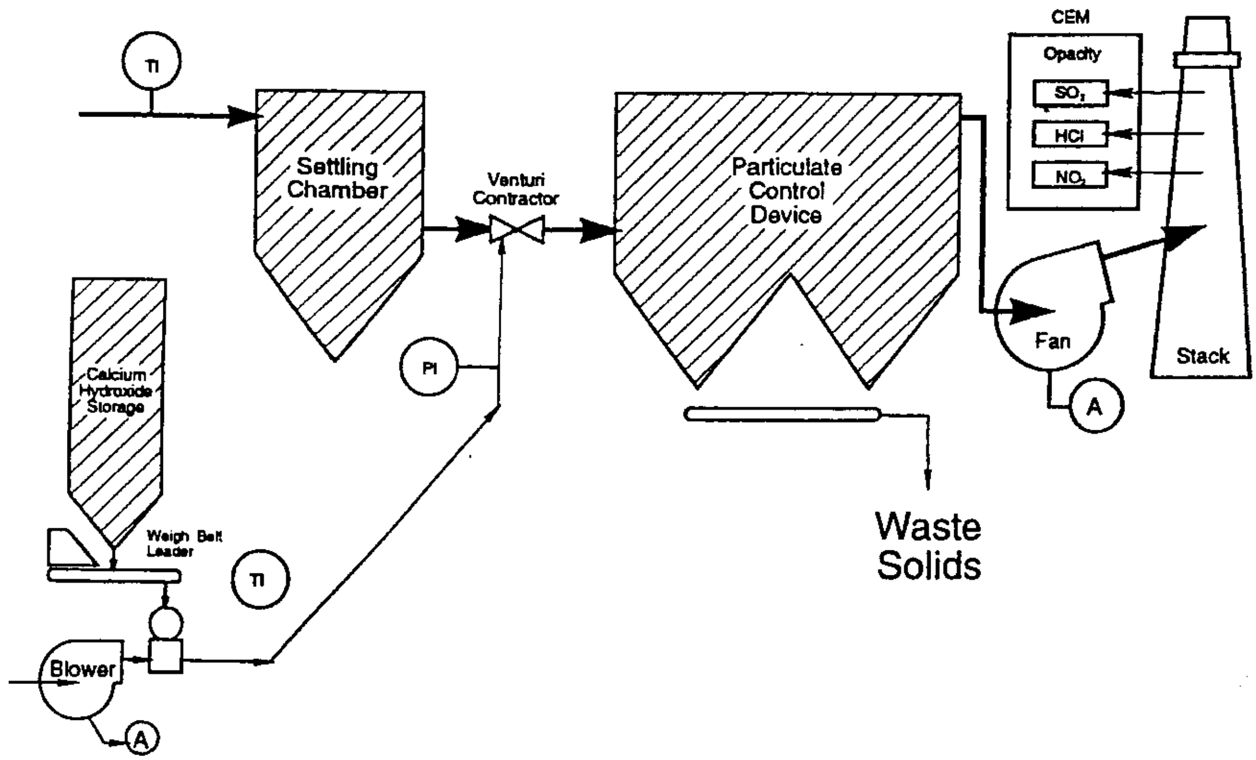


Figure 5-1. Components Of A Spray Dryer Absorption System



Legend: A--Motor current gauge
PI--Pressure gauge
TI--Temperature gauge

Gas stream flow

Material (liquid/solid) flow

Figure 5-2. Components Of A Dry Injection Adsorption System

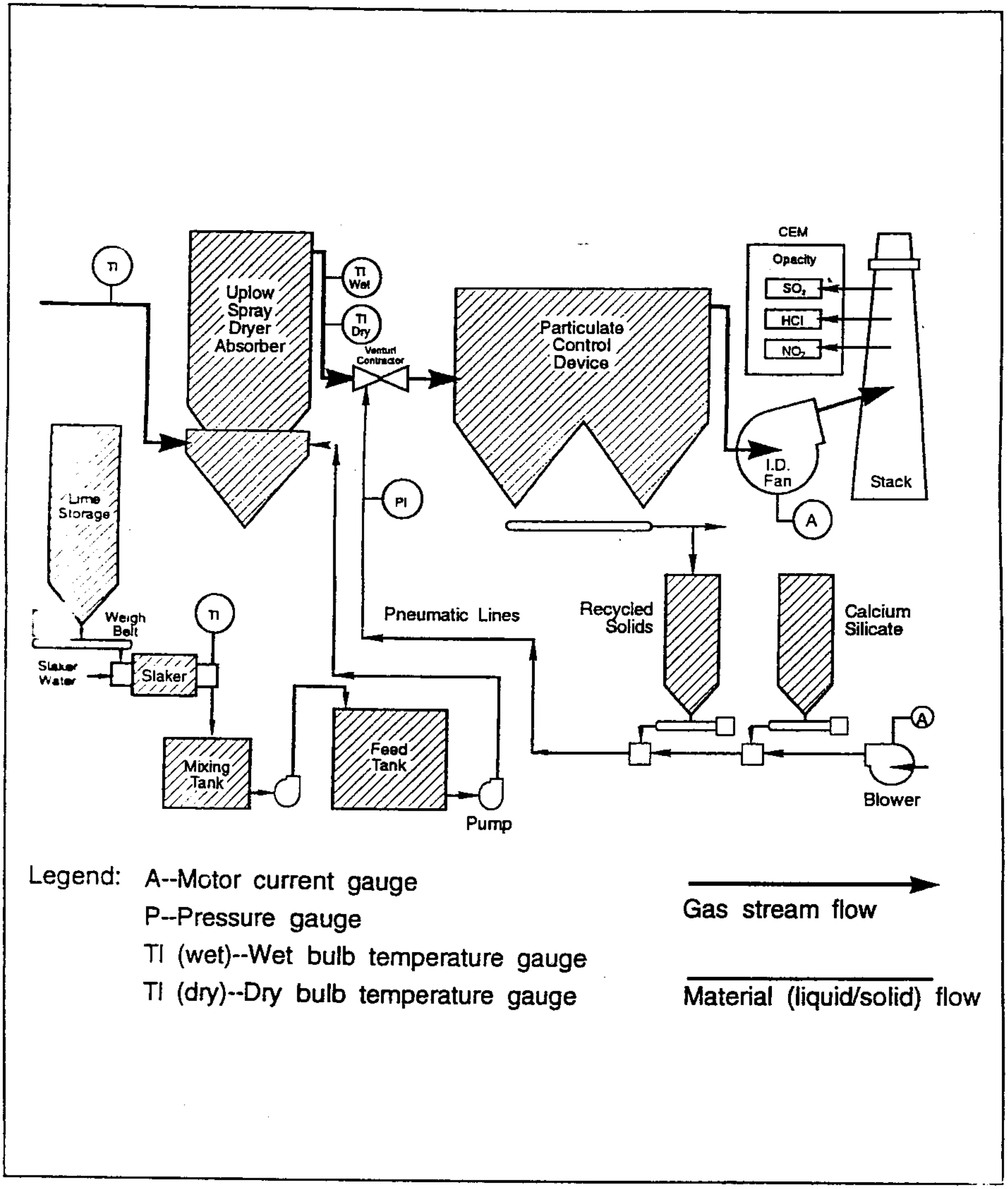


Figure 5-3. **Components Of A Combination Spray Dryer Absorption/ Dry Injection Adsorption System**

How Do The Techniques Differ?

The major differences among the various systems are the physical form of the alkaline reagent (whether the reagent is finely ground or is larger, for example), and the way the system brings the gas stream into contact with the reagent. Dry injection adsorption systems also use more alkaline reagent than do the other two categories of dry scrubbers. Another difference in the three systems is that spray dryer absorption and combination spray dryer absorption/dry injection adsorption systems are much more complicated than are dry injection adsorption systems. In general, absorbers are usually used alone, but adsorbers are almost always used in conjunction with fabric filters or ESPs.

Differences among systems include:

- *Alkaline reagent form.*
- *Method by which the gas stream and reagent are brought into contact.*

How Efficient Are These Systems?

All three categories of dry scrubbing systems appear to remove pollutants very efficiently. In most cases, continuous emissions monitors (CEMs) can directly indicate how well the system is performing. For all three types of dry scrubbers, agency inspectors should first review the CEM data that has been collected since the last inspection. Subsequent inspection steps should vary, depending on the dry scrubber's components and on its operating principles.

CEM data can be useful in assessing system performance.

Spray Dryer Absorbers

Spray dryer absorbers (Figure 5-1) use droplets of a thick liquid to absorb pollutants. The collected, semi-dry droplets fall to the bottom of the absorber vessel. They are then either recycled or sent to a landfill. Fabric filters and ESPs are usually not used with spray dryer absorbers because the spray dryer droplets are too wet to be collected in those devices.

The alkaline reagent is prepared as a **slurry** (a thick liquid) containing 5 to 20 percent solids by weight. To improve absorption, this slurry is atomized (forced into droplet form) in a large absorber vessel, where it remains for 6 to 20 seconds. It is in this absorber vessel that absorption takes place. The two primary types of atomizers used are **rotary atomizers** and **air-atomizing nozzles**. Generally, an absorber will have only one rotary atomizer; however, some have as many as three.

The shape of the absorber vessel varies with each dry scrubber application, depending on the slurry spray pattern used and the time required for droplet evaporation. With air-atomizing nozzles, less time is needed for droplet evaporation; therefore, the vessel can be shorter.

How Important Is Evaporation?

In a spray dryer absorber, it is important that all of the slurry droplets evaporate so they cannot reach the side walls of the absorber vessel or

Slurry droplets must evaporate before they reach the side walls and before they leave the absorber.

leave the absorber with the gas stream. If the droplets do not evaporate, material will accumulate on the side walls or on the bottom of the absorber. This will impede drying, and, as a result, the unit might have to be shut down and the accumulated material removed. Proper slurry drying is achieved by generating small slurry droplets, providing proper flue gas contact, and using moderately hot flue gases.

Drying too rapidly can reduce pollutant collection efficiency.

Drying too rapidly can also be a problem. It may reduce pollutant collection efficiency. Because the primary removal mechanism is pollutant absorption into the slurry droplets, the slurry droplets and the gas stream must remain in contact long enough to allow absorption. To prevent the droplets from drying too quickly, spray dryer absorbers operate with exit gas temperatures that are 90 to 180 °F above the saturation temperature. Therefore, it is important to inspect temperature monitors.

How Do Rotary Atomizers And Nozzle-Type Atomizers Differ?

Rotary atomizers generate very small droplets in a broad spray pattern.

In rotary atomizers, a thin film of slurry is fed to the top of the atomizer disk as it rotates at speeds of 10,000 to 17,000 rpm. These atomizers generate very small slurry droplets (with diameters of ~100 mm). The spray pattern is inherently broad because of the geometry of the disk.

Nozzle-type atomizers can operate over wider variations in gas flow rate than can rotary atomizers. However, they do not have slurry feed adjustment capabilities.

In nozzle-type atomizers (picture a garden hose as an example of a nozzle-type atomizer), high-pressure air (typically 70 to 90 psig) forces existing slurry droplets to break into smaller droplets (70 to 200 mm). Generally, this type of atomizer can operate over wider variations in gas flow rate than can a rotary atomizer. The nozzle atomizer, however, does not have the slurry feed adjustment capability that the rotary atomizer has.

What Kind Of Reagent Is Used In A Spray Dryer Absorber?

The most common alkaline material used in a spray dryer absorber is pebble lime or calcium carbonate ($CaCO_3$). This material must be slaked to prepare a reactive slurry (scrubbing liquor) for acidic gas absorption. Slaking occurs when water is added to convert calcium oxide (CaO) to hydrated lime or to calcium hydroxide, $Ca(OH)_2$. Proper slaking conditions are important to ensure that the resulting $Ca(OH)_2$ slurry has the proper particle size distribution, and that no particle coating has occurred because of contaminant precipitation in the slaking water.

Therefore, the quality of the slaking water, the feed rate of the lime, and the slurry exit temperatures are important. A variety of subtle changes in the slaker can affect the reactivity of the scrubbing liquor. Any shifts from baseline operating conditions might have been caused by changes in the scrubbing liquor rather than by operating problems with the dry scrubber.

What Problems Can Arise With This Type Of System?

One problem with spray dryer absorbers is that the slurry feed line to the atomizer can become plugged. Also, line scaling (coating) can be severe because of the very high pH of this liquor. The flow rate of the liquor to the atomizer is usually monitored by a magnetic flow meter. This instrument is vulnerable to scaling because the flow-sensing elements are on the inside surface of the pipe.

Plugging of the feed line to the atomizer can be a problem.

Can The Reagents Be Recycled?

Recycling the solids collected in the absorber vessel is an important function in most spray dryer systems. These solids can be added to the slurry, thereby improving the drying of the droplets. Recycling also reduces reagent waste. The condition of the absorbent (e.g., how many times it has been recycled) is continuously monitored, and "spent" (no longer effective) absorbent is sent to a landfill.

Whereas some adsorption takes place within the absorber vessel, most of the adsorption takes place in the baghouse.

Dry Injection Adsorption Systems

Dry injection adsorbers (Figure 5-2) usually operate with a baghouse. The adsorber itself serves primarily as a mixing chamber for the reagent and the gas stream. Within the adsorber vessel, the reagent is fluidized (made to flow like a liquid) and mixed with the gas stream. Some pollutant adsorption takes place within this vessel, but most of the adsorption actually takes place in a baghouse.

Dry injection adsorption systems use finely divided (powdered) alkaline material to adsorb acidic gaseous pollutants. The most common alkaline material used is $Ca(OH)_2$. The $Ca(OH)_2$ is approximately the consistency of talcum powder: its particle size is 90 percent by weight, passing a 325-mesh screen. This particle size ensures that there is sufficient $Ca(OH)_2$ surface area to keep the system working efficiently.

The reagent is transported to the dry scrubber by a positive pressure pneumatic conveyor. This initial fluidization breaks up any clumps of reagent formed during storage. The airflow rate in the pneumatic conveyor is kept at a constant level (regardless of system load) to ensure proper reagent particle size.

To complete fluidization, the $Ca(OH)_2$ is injected so that it and the gas stream flow in opposite directions. A venturi scrubber is used to provide the turbulent action necessary to mix the gas stream and reagent; the gas stream is forced through a constriction, which increases its velocity and turbulence. The $Ca(OH)_2$ particles and any uncollected particles entrained in the gas stream are then collected in a fabric filter.

When And Where Does Adsorption Occur?

Pollutant removal efficiency of dry injection scrubbers depends on:
- *Size of reagent particles.*
- *Adequacy of dust cake formation.*
- *Quantity of reagent injected.*

Adsorption of acidic gases and or; nic compounds, if present, occurs primarily while the gas stream passes through the dust cake on the fabric filter bags. (This dust is composed of $Ca(OH)_2$ and uncollected process particles.) The efficiency with which pollutants are removed depends on the size of the reagent particles, the adequacy of dust cake formation, and the quantity of reagent injected.
The amount of $Ca(OH)_2$ used in dry injection systems is three to four times the amount that is theoretically needed to adsorb the pollutants. This amount is used to ensure adequate adsorption.. The feed rate is much higher than the feed rate for spray dryer absorber systems. Therefore, dry injection adsorption is not useful for very large systems because of the extra adsorbent needed to ensure that particles are adsorbed and collected.

In one design of the dry injection system, solids collected by the dry scrubber are recycled. The primary purpose of the recycling is to reuse the reagent and to reduce overall $Ca(OH)_2$ costs.

Combination Spray Dryer Absorption/Dry Injection Adsorption Systems

Combination spray dryer/dry injection systems use both absorption and adsorption for removal of acid gases.

In combination spray dryer absorption/dry injection adsorption systems, the acidic flue gas is first treated in an upward-flow spray dryer absorber (Figure 5-3). A series of $Ca(OH)_2$ sprays near the bottom of the absorber vessel are used to generate droplets.

After passing through the upflow chamber, the partially treated flue gas passes through a venturi scrubber section, where it is exposed to a second reagent, a suspension of calcium silicate ($CaSiO_4$) and lime. The purpose of the second reagent is to improve the dust cake characteristics in the downstream fabric filter, thereby improving acidic-gas removal in the dust cake. The $CaSiO_4$ reportedly improves dust cake porosity and serves as an adsorbent for the acidic gases.

Solids collected in the fabric filter can be recycled to the venturi scrubber section. Recycling reduces the amount of new reagent that is needed and helps to further remove pollutants.

Typical Emission Points

Unintentional emissions can occur at corrosion and erosion points.

The uncollected effluents from a dry scrubber are usually emitted through the scrubber's stack or vent when a malfunction occurs. Emissions can also occur at corrosion and erosion points in the scrubber and associated ductwork.

Typical Inspection Areas

The major inspection areas for the dry scrubber system include:

- Stack or vent exit.
- Physical condition of unit (corrosion and erosion).
- Spray nozzles (inspect only when out of service).
- Internal physical condition (inspect only when out of service).

If a dry scrubber is used to treat gas streams having high HCl concentrations (such as municipal incinerators), corrosion can be a problem. Because of the potential corrosion problems, inspections should include checks for air infiltration and a visible evaluation of potential corrosion sites.

Summary

Dry scrubber operations use absorption and adsorption to remove SO_2, HCl, HF, and other acidic gaseous pollutants from gas streams. These removal systems are used primarily on municipal waste incinerators.

The most important dry scrubbing techniques are spray dryer absorption, dry injection adsorption, and combination spray dryer absorption/dry injection adsorption.

Review Exercises

1. Which of the following is a major category of dry scrubbing techniques?

   a. Spray dryer absorption.
   b. Dry injection adsorption.
   c. Combination spray dryer absorption/dry injection adsorption.
   d. All of the above.

2. True or false? The alkaline feed requirements are much higher for dry injection adsorbers than for the other two categories of dry scrubbers.

3. Which of the following particulate matter control devices are less commonly used in conjunction with dry scrubbers?

   a. Fabric filters.
   b. ESPs.
   c. Wet scrubbing systems.

4. True or false? In spray dryer absorbers, the length-to-diameter ratio for rotary atomizers is much larger than that for adsorber vessels using air-atomizing nozzles.

5. Proper slurry drying is an important operating principle of spray dryer absorbers because:

   a. Otherwise, materials will accumulate on the side walls or on the bottom of the absorber, which further impedes drying.
   b. Drying that is too rapid can reduce pollutant collection efficiency, because the primary removal mechanism is absorption into the droplets.
   c. It enhances the generation of large slurry droplets, which can absorb more materials.
   d. a and b.
   e. a and c.

6. Slaking is the addition of ________ to convert CaO to ________.

7. Dry injection adsorption systems use $Ca(OH)_2$ as a reagent that is approximately the consistency of:

   a. Slurry
   b. Talcum powder
   c. Sand
   d. Gravel

8. True or false? The pollutant removal efficiency of a dry injection adsorber depends on the reagent particle size, the adequacy of dust cake formation, and the quantity of reagent injected.

9. True or false? A combination spray dryer absorption/dry injection adsorption system uses a $Ca(OH)_2$ reagent in the upflow chamber and a suspension of $CaSiO_4$ and lime in the venturi section.

Answers

1. d. All of the above.
2. True
3. c. Wet scrubbing systems.
4. c. False. The ratio is much smaller because less time is needed for evaporation.
5. d. a and b.
6. water; $Ca(OH)_2$
7. b. Talcum powder
8. True
9. True